



Summary of Preliminary Ecological and Human Health Risk Evaluations

Prepared for the Elizabeth Mine Community Advisory Group (EMCAG)

Elizabeth Mine
Strafford/Thetford,
VT

Summary Prepared for

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1.0 Introduction

This summary of the preliminary upcoming Ecological and Human Health Risk Evaluation Report provides an evaluation of the impacts to human and ecological receptors (primarily fish and other aquatic organisms) as a result of the release of Acid Mine Drainage (AMD) from the Elizabeth Mine in Strafford and Thetford, VT. (See Figure 1 for Site location). The preliminary risk assessment activities and findings presented in this summary were developed as supporting information for the Engineering Evaluation and Cost Analysis (EE/CA) Report. The EE/CA is being developed as part of a possible Non-Time Critical Removal Action (NTCRA).

This summary is also intended to provide the Elizabeth Mine Community Advisory Group (EMCAG) and other stakeholders the opportunity to further participate in the development of the EE/CA by reviewing and commenting upon this initial evaluation of risks posed by the current conditions at the mine site. A more detailed Preliminary and Ecological and Human Health Risk Evaluation Report is expected to be released for public review by October 2001. EPA will also develop a formal Baseline Ecological Risk Assessment (BERA) and Human Health Risk Assessment for the entire site as part of the remedial investigation and feasibility study (RI/FS).

2.0 Cleanup Implementation Strategy

In September 2000, the EMCAG unanimously supported the Site's listing on the EPA Superfund National Priorities List (NPL) of hazardous waste sites. In June 2001, the Site was officially listed on the NPL. The Superfund cleanup of the Elizabeth Mine site is being implemented as a two-phase program. The first phase, or "NTCRA", consists of an early cleanup action that targets the AMD generated by the tailings and waste rock. The second, or "Remedial" phase, will involve a comprehensive investigation and subsequent cleanup action of any remaining threats posed by the Site. Areas of the site that will be subject to further evaluation in the comprehensive investigation phase or RI/FS include: air vent discharge; south open cut discharge; south mine discharge; underground workings; groundwater; and sediments of the West Branch of the Ompompanoosuc River (WBOR) and Copperas Brook. See Figure 2 for a flow chart of the cleanup implementation strategy.

EPA embarked upon a substantial data-gathering program in the spring of 2000 to validate the existing data and provide a database for cleanup option development and risk evaluation. EPA collected surface water and sediment chemistry data, performed surface water and sediment toxicity tests, and performed surveys of bottom dwelling organisms (benthic epifauna and infauna) and algae. EPA evaluated the existing data regarding fish abundance and the benthic communities collected by the Vermont

Agency of Natural Resources (VTANR). EPA also evaluated the fish abundance and fish tissue chemistry study completed by the US Army Corps of Engineers (USACE). To assess human health impacts, EPA sampled the dust, air, drinking water, and soil of several residences adjacent to the site. The data collected by EPA from April 2000 to December 2000, coupled with the VTANR and USACE studies, form the basis for the conclusions presented in this summary.

3.0 Basis for Cleanup Action

A Superfund cleanup action must be based upon a finding that there is a current or future potential threat to human health and/or the environment. The human health and ecological risk assessment process provides a framework for this determination. The risk assessment also helps to identify the contaminants that are causing the impacts, so that cleanup options can be developed. The risk assessment is a critical step in the Superfund process. EPA would not undertake a cleanup action if the result of the risk assessment indicated that the level of risk to human health or the environment was within EPA's acceptable risk range.

The human health risk assessment component of this summary is based upon a preliminary screening of the site data against numerical concentrations that EPA considers acceptable ("safe") for long-term human contact. EPA also requested an assessment of the site data by the Agency for Toxic Substances and Disease Registry (ATSDR).

For the ecological component, a two-step evaluation process was used. First, the data was reviewed to identify the chemicals most likely to cause an impact. This data was used to develop a Hazard Quotient (HQ), which is equal to the site contaminant concentration divided by the safe concentration for ecological receptors. The HQ represents how many times greater a given sample concentration is than the safe level.

The second step of the ecological risk assessment involves the use of biological measurements of fish abundance, benthic community structure, and toxicity tests. Contaminant levels above the safe concentration do not always result in a significant impact to aquatic organisms, biological assessments were used to provide a more direct evaluation of the impact from site contaminants.

4.0 Site Setting and Conditions

Mining and processing of ore materials at the Elizabeth Mine Site, located in the towns of Strafford and Thetford, Vermont, began over 200 years ago. The earliest operations at the Site involved the processing of ore materials for the production of copperas, an iron-sulfate salt used for dye and disinfectant manufacturing throughout the 1800s. Extraction of copper from the same ore materials occurred on an intermittent basis from about 1830 to 1958. A more detailed discussion of the historical significance of the Elizabeth Mine can be found in “Statement Of Site Limits, National Register Eligibility, And Potential Resources in the Proposed APE” (October 2000 – Hartgen Associates and Arthur D. Little, Inc.) and “Historical Context and Preliminary Resource Evaluation of the Elizabeth Mine” (May 2001 – Public Archeology Laboratory and Arthur D. Little, Inc.)

Waste materials from the mining and milling operations exist today as tailings, waste rock piles, heap-leach piles, and smelter slag at various locations around the mine site. When exposed to natural conditions at the ground surface, these materials break down and release metals and acid contamination to Copperas Brook and the WBOR. This contamination is known as AMD. A variety of metal contaminants are present in the surface water of the WBOR and associated sediments, including (but not limited to) aluminum, cadmium, chromium, cobalt, copper, iron, manganese, and zinc. Studies by EPA and others show that this contamination has had a negative impact on the overall quality and ecological health of Copperas Brook (which flows through the tailings) and a stretch of the WBOR downstream from the mine. The previously released Site Summary Report (ADL, October 2000), Site Conditions Report (ADL, February 2001), and Alternatives Analysis Report (ADL, April 2001) contain supporting technical information related to environmental and historic concerns at the Site.

The Elizabeth Mine is located in the Copperas Brook watershed which drains into the West Branch of the Ompompanoosuc River, approximately 5.7 miles (9 kilometers) upstream from the Union Village dam.

The Ompompanoosuc River empties into the Connecticut River approximately 3 miles (5.5 kilometers) downstream of the Union Village Dam. Copperas Brook flows from its headwaters near TP-3 over a distance of nearly one-mile to its confluence with the West Branch of the Ompompanoosuc River.

Upper Copperas Brook flows from the base of Tailings Pile 3 (TP-3), through a divide in Tailings Pile 2 (TP-2), onto the surface of Tailings Pile 1 (TP-1), where it enters a small pond (a former settling pond for tailing fines). A decant tower diverts water from the surface of TP-1 through concrete pipes to a discharge point at the northeast corner of the tailings pile. Water from the pipe combines with discharge seeps from the base of

TP-1 to form Lower Copperas Brook in the wooded areas and wetlands below the tailings.

The Copperas Brook watershed is approximately 300 acres in size, has an overall vertical drop of approximately 750 feet, and a flow range of approximately 50 to over 2000 gallons per minute (gpm) at the confluence with the WBOR. The watershed experiences a wide range in surface water flows. The upper portion of the watershed normally experiences low flows in the range of 2 to 10 gpm at EPA's sample Location Number 2 (below TP-3). Storm event flow of over 300 gpm has been measured at the Location 2 gauging station. The upper tailings (TP-3) sit primarily on bedrock or a thin veneer of overburden material. The lower tailings piles (TP-1 and TP-2) appear to be underlain by a thick glacial till of very low hydraulic conductivity. Although a thin sand unit has been found between the tailings and the till, it is believed that the till layer limits the flow of groundwater into the tailings. Approximately 80-90% of the water within the tailings results from surface water run-on from Upper Copperas Brook; the remaining 15 to 20% is provided mostly by direct precipitation and snowmelt with a small component of flow from ground water.

Preliminary conclusions from the EPA investigations conducted to date suggest the following:

- The tailings and waste rock piles of TP-1, TP-2, and TP-3 are the major source areas for AMD and metals loading to the WBOR.
- While TP-3 represents only 12 of the almost 50 acres of mining waste, TP-3 appears to be a significant contributor of metals and acid loading.
- The South Open Cut and Air Vent are less significant sources of contaminants.
- The North Open Cut is not considered a contamination source at this time, but the associated underground (flooded) workings are considered to be a source of contamination.
- The South Mine is considered a source of contamination for the Lord Brook watershed.
- A separate source of contamination (Ely Mine) affects water quality in the EBOR. (The Ely Mine is not addressed in this summary.)

5.0 Risk Assessment Sampling Program

5.1 Surface Water

To assess the extent of environmental impact from the Elizabeth Mine, EPA collected surface water samples throughout the Elizabeth Mine area. Sample locations are broadly divided into the following nine groupings: (See Figure 3 for sample locations and groupings).

- *Contamination Source Areas* includes locations within the Copperas Brook watershed and the Air Vent prior to discharge into the WBOR.
- *Unaffected tributaries to the West Branch of the Ompompanoosuc River* includes Sargent Brook, Abbott Brook, Fulton Brook, Jackson Brook, Bloody Brook, and Lower Lord Brook.
- *Affected tributaries to the WBOR* includes Upper Lord Brook, two intermittent streams on Mine Road, and an intermittent stream within the Copperas Brook drainage.
- *WBOR upstream of Mixing Zone* includes the WBOR upstream from the Air Vent and Copperas Brook.
- *WBOR Mixing Zone* includes the section of the WBOR from Copperas Brook confluence to a point approximately 2500 feet downstream.
- *Air Vent Mixing Zone* includes locations within the WBOR between the Air Vent and the confluence with Copperas Brook – approximately 2500 feet in length;
- *WBOR Below Mixing Zone* includes the stretch of WBOR between the EBOR/WBOR confluence and EPA sample location No. 42.
- *East Branch of the Ompompanoosuc River (EBOR)*.
- *WBOR below confluence of EBOR and WBOR*.

EPA has collected surface water samples at a total of 46 locations throughout the Elizabeth Mine area for use in the ecological risk assessment. Surface water sampling is summarized in the table below. See Table 1 for a summary of the sample locations and samples events and Table 2 for a summary of the data groupings described above.

Sampling Event	Description of Event	Number of Occurrences
Weekly	April – May 2001: Weekly stream sampling at 6 locations to evaluate spring runoff metals and pH loading	5
Monthly	April, May, Oct. – Dec. 2001: Monthly sampling – subset of locations	6
Synoptic – all stations	June, July, September 2001- All locations	3
Episodic (Storm Event)	June and July 2001– Locations 2,6,7,8,13,16	2

The number of locations and analyses varied between sampling events as the program was refined and as data gaps were identified, as described below:

- April 2000: a subset of 17 locations was sampled for total metals, alkalinity, total suspended solids (TSS), total dissolved solids (TDS) and hardness.
- May 2000: 45 locations were sampled for total metals, dissolved metals, alkalinity, TSS, TDS, hardness, total organic carbon (TOC), acidity and cyanide (CN), while a subset of 9 locations were sampled for biological oxygen demand (BOD), total Kjeldahl nitrogen (TKN), and ammonia (NH₃).

- June 2000: 32 locations were sampled for total metals, alkalinity, TSS, TDS, hardness, and acidity (lab sample handling errors resulted in a lack of confidence for several June-event samples).
- July 2000: 46 locations were sampled for total and dissolved metals and cyanide, while 41 locations were sampled for alkalinity and anions (negatively charged ions), 42 sampled for hardness, 11 sampled for BOD, TKN, and NH_3 , and 10 were sampled for volatile organic compounds (VOCs), polychlorinated organic compounds (PCBs), pesticides, and Base Neutral Acids (BNA).
- September 2000: 49 locations were sampled for total and dissolved metals 35 locations for alkalinity, 34 locations for hardness and acidity, 13 locations for CN, and 5 locations for BOD, TKN, and NH_3 .
- December 2000: 17 locations were sampled for total metals and hardness.

5.2 Sediment

Two sediment sampling events were completed in 2000. The first was completed in July and the second in September. In July 2000, 41 locations were sampled for total metals, acid volatile sulfide/simultaneously extracted metals (AVS/SEM), grain size, and TOC. One location was sampled for cyanide, and five locations were sampled for VOC, BNA, pesticides and PCBs. In October 2000, 11 of the 41 locations were sampled for total metals and AVS/SEM.

5.3 Algae

Algae samples were collected by Bob Genter of Johnson State College for 14 stream locations in the WBOR, some corresponding to benthic organism sampling sites. Metals analyses of the algae samples were conducted by Woods Hole Laboratories.

5.4 Benthic Organisms

A benthic macroinvertebrate survey was performed in conjunction with October 2000 surface water and sediment sampling program. A total of 22 locations were sampled; 5 for bottom dwelling organisms (epifauna) only, 2 for sediment dwelling organisms (infauna) only, and 15 for combined epifauna and infauna. A total of 59 replicate samples have been analyzed to date; the remainder have been archived for future analysis. Samples were collected using an 18-inch by 9-inch rectangular dip net. Taxonomic analysis and bioassessment of epifauna was conducted in accordance with guidance provided by VTDEC (July 2000). Epifauna data were analyzed using the following metrics:

- Density
- Taxa richness
- EPT index
- % Oligochaeta
- % modal affinity of Orders

- Hilsenhoff Biotic Index, and
- Pinkham-Pearson Coefficient of Similarity¹

5.5 Fish

The abundance of fish in the WBOR, above and below the confluence with Copperas Brook, and in selected WBOR tributary streams has been evaluated by the USACE and VTANR. In addition, the USACE (1990) collected twenty blacknose dace (*Rhinichthys atratulus*) from each of four collection areas of the WBOR (upstream (Area I) and downstream (Areas II, III, and IV) of the confluence with Copperas Brook). Fish tissue samples (whole fish from which the entire gastrointestinal tract had been excised) were analyzed for selected metals, including barium, cadmium, chromium, copper, iron, lead, manganese, and zinc. The VTANR (Langdon 2001), collected information on fish populations from three tributaries to the WBOR (Sargent, Copperas, and Lord Brooks). EPA plans to perform an independent fish tissue sampling program for use in the Baseline Human Health and Ecological Risk Assessment.

5.6 Residential Well Sampling

Residential water supplies have been sampled as part of the preliminary investigations. Each residential well was initially sampled for VOCs, Semivolatile Organic Compound (SVOCs), and metals. Subsequent samples were only evaluated for metals and sulfides.

5.7 Residential Soil Sampling

Three soil samples were collected from each of three adjacent residences in July 2000. An additional 30 samples were collected from each of the same three residences in November 2000.

6.0 Ecological Risk Assessment Approach

6.1 Overview

Since April 2000, EPA has gathered and analyzed information from the Elizabeth Mine site to characterize the nature and extent of contamination and associated risks from waste materials and the mine workings. Surface water and sediment samples have been collected on a regular basis at sampling stations throughout the WBOR watershed in the Elizabeth Mine area.

The ecological risk evaluation follows a two-step approach to the development of the risk characterization. As part of the first step, chemical data are evaluated to determine which of the chemicals found in the surface water and sediments are Contaminants of Concern (COCs). COCs are the contaminants that are believed to be most responsible

for the impact to the receptors at the Site. The identification of COCs greatly simplifies the risk characterization process and eliminates spending time and effort on chemicals that have minimal impact.

The second step involves the use of biological measures of impact, including toxicity testing, fish surveys, and benthic surveys. The Vermont Water Quality Standards (VTWQS) consist of both numerical and biological criteria to assess compliance with the standards. It is widely acknowledged, by EPA and VTANR, that biological measures provide a better indicator of actual impact on an ecological system than numerical criteria alone.

6.2 Step 1: Contaminants of Concern (COCs)

A Hazard Quotient (HQ) method was used to identify COCs and calculate *potential* ecological risks from metal contaminants for each of the nine general site areas/data groupings (Source Area, Mixing Zone, etc.). This approach uses scientifically established safe levels of exposure for aquatic organisms (fish, bottom dwelling organisms), and well defined and established chemical-specific exposure levels that are believed to cause toxic effects on receptors in aquatic ecosystems. The HQ is equal to the quotient of the site contaminant concentration divided by the acceptable (“safe”) concentration. It represents how many times greater a given sample is than the safe level. The numerical VTWQS were used as the safe level, when available. Several constituents in surface water did not have a VTWQS. For these instances, EPA identified a scientifically valid safe level from available literature. There are no Vermont standards for sediment; therefore, all of the safe levels for sediments were from EPA accepted sources. Table 3 lists the criteria used as the safe level in calculating the HQs in surface water and sediment.

The HQ is calculated by dividing the metal concentration (at any given location) by its corresponding, medium-specific benchmark (e.g., VTWQS). For example, the HQ for copper at a hypothetical location can be expressed as follows:

$$\text{HQ} = \frac{200 \text{ ug/l (concentration from sample)}}{10 \text{ ug/l (VTWQS or safe level)}} = 20$$

where the copper concentration in surface water is 200 ug/l and the (hypothetical) hardness-adjusted criteria (freshwater biota, chronic exposure) is 10 ug/l.

Because more than one metal of concern is present in surface water, sediments and soils in the Elizabeth Mine area, chemical-specific HQs were added together to estimate the total risk to ecological receptors (e.g. fish) or humans. This sum is called the Hazard Index (HI), and is based on the assumption that risk from different chemicals is additive. In other words, the total potential risk to ecological receptors or humans is the sum of risks posed by individual contaminants. A HQ or HI greater than one indicates a potential harm to ecological receptors and that further evaluation using biological measures is warranted.

The following is a summary of the key findings of the evaluation of the chemical data and development of hazard quotients.

6.2.1 Surface Water Chemistry

The surface water data collected since April 2000 indicate that 15 contaminants are detected at concentrations above VTWQS or EPA criteria, including: aluminum, barium, cadmium, chromium, cobalt, copper, cyanide, iron, lead, manganese, selenium, silver, thallium, vanadium, and zinc. VTWQS are available for cadmium, chromium, copper, cyanide, iron, lead, selenium, and zinc. EPA used reference material to establish the criteria for aluminum, barium, cobalt, manganese, silver, thallium, and vanadium.

Of these fifteen contaminants, nine appear to be clearly related to the source material based on their concentration and frequency of occurrence in the source area samples: aluminum, cadmium, cobalt, copper, iron, manganese, selenium, silver, and zinc. These contaminants have been designated as COCs.

The remaining six contaminants (barium, chromium, cyanide, lead, thallium, and vanadium) warrant further evaluation as part of the RI/FS to determine if they are truly site-related, based on concerns such as data quality, frequency of occurrence, and naturally occurring background levels. Table 4 presents the fifteen contaminants of potential concern, and highlights the list of contaminants designated as COCs for the purposes of this summary.

Figure 4 provides a graphical summary of the surface water samples that exceed applicable standards for the six COCs that represent the majority of the HI. Figure 4 shows that aluminum is the only contaminant that is consistently detected above acceptable criteria at the upstream (Reference) locations. Figure 4 also shows that the concentration of contaminants in the Source Area and the Mixing Zone Area are frequently greater than the accepted criteria. The percent of samples with concentrations greater than accepted criteria drops with distance downstream from the confluence with Copperas Brook.

Figure 5 compares the HQ for the six COCs for each area (e.g. Source Area, Mixing Zone) to the levels detected upstream of the source area using a ratio of the hazard quotients. For example, aluminum is detected at concentrations in the Mixing Zone Area that are 5 times higher than the Upstream of Mixing Zone Area.

When evaluated together, Figures 4 and 5 provide a simple way to view the surface water chemistry in the vicinity of the Elizabeth Mine. The Hazard Quotients for surface water are summarized in Tables 5 and 6.

Surface water quality within Copperas Brook and the Mixing Zone of the WBOR is clearly impacted by acid mine drainage from the Site. The levels of contaminants detected in Copperas Brook and the Mixing Zone are many times higher than the Vermont Water Quality Standards and EPA accepted criteria. Significant impact to the

aquatic organisms would be expected as a result of this water quality. A decrease in metals concentrations is observed with distance downstream of the Copperas Brook confluence. Copper is the only COC to remain significantly above upstream concentrations beyond Union Village Dam at EPA Location 44.

6.2.1.1 Summary of Key Findings for Surface Water

- Concentrations of aluminum, cadmium, chromium, cobalt, copper, iron, manganese, silver and zinc in the WBOR Source Area are substantially higher than VTWQS, other EPA accepted criteria for surface water, and the upstream (Reference) areas.
- Six of these contaminants: aluminum, cobalt, copper, iron, manganese, and zinc are also detected in concentrations above VTWQS and EPA accepted criteria well past the confluence of the WBOR and Copperas Brook.
- Copperas Brook and a section of the WBOR just below the confluence with Copperas Brook have the highest concentrations of metals in surface water within the study area.
- Hazard Quotients for copper, iron, aluminum and zinc are significantly higher (1 to 3 orders of magnitude, or 10 to 1,000's of times higher) in the Source Area and Mixing Zone than in upstream (Reference) Areas; the corresponding Hazard Indices show similar trends.
- Maximum concentrations of metals in the WBOR within the Mixing Zone Area exceed applicable criteria (Vermont Water Quality Standards or other EPA criteria) by a factor of 201 for aluminum, 9 for cobalt, 63 for copper, 50 for iron, and 17 for manganese.
- Although aluminum is consistently elevated in upstream locations, the levels found in the Source Areas and Mixing Zone are substantially higher than the concentrations detected at upstream locations.
- The point at which the WBOR no longer exceeds VTWQS numerical criteria is not known. Elevated levels have been sporadically detected at the furthest downstream surface water sampling station, below Union Village Dam.

6.2.2 Sediment Chemistry

Samples of sediment were collected at each surface water sampling location plus several additional locations and submitted for metals analysis during two sampling events (June and September/October 2000). Hazard Quotients and Hazard Indices were calculated for sediments at for each of the identified data groups (Source Area, Mixing Zone). The hazard quotients for sediments are summarized in Tables 7 and 8.

Aluminum, iron and zinc concentrations in sediments do not display the strong Site-related pattern observed for copper. Source Area concentrations for these metals are clearly elevated with respect to the upstream (Reference) area, however, the downstream concentrations of iron and zinc are fairly close to upstream concentrations. Hazard Quotients and associated Hazard Indices for metals below the confluence of the EBOR and the WBOR are comparable to the Mixing Zone, suggesting that little to modest attenuation of metals contamination in sediment occurs with increasing distance from the Source. It should be noted that the Hazard Index for the Air Vent Mixing Zone was not greater than the upstream areas suggesting that the air vent may not represent a

significant loading to the sediments or that the air vent loading is transported downstream due to scour and re-deposition.

The sediment results for the Source and Mixing Zone of the WBOR indicate that certain metals are present in concentrations that could have an adverse effect on aquatic and sediment dwelling organisms. Copper levels in sediment, like surface water, continue to be elevated below Union Village Dam. Copper has a sediment HQ of 5 for the section below Union Village Dam.

6.2.2.1 Summary of Key Findings for Sediment

- Concentrations of copper, iron, manganese, and zinc are higher in the Source Areas and Mixing Zone Area than upstream (Reference) levels.
- Copperas Brook and a section of the WBOR just below the confluence with Copperas Brook have the highest concentrations of metals in sediment within the study area.
- Maximum concentrations of metals in the Mixing Zone Area of the WBOR exceed applicable criteria by a factor of 11 for copper, 2 for iron, 2 for manganese and are slightly above the criteria for zinc.
- Hazard Quotients for copper and iron are much higher in the Source Area and Mixing Zone than in the Upstream of Mixing Zone Area; the corresponding Hazard Indices show similar trends.
- Elevated levels of copper (130 mg/kg), resulting in a Hazard Quotient of 6, have been detected below Union Village Dam, as far as the Connecticut River at EPA Location 38.

6.2.3 Summary of Step 1

The surface water and sediment data document the potential for severe impact to Copperas Brook and a section of the WBOR as a result of the discharges from the Source Areas. All of Copperas Brook and a section of the WBOR have failed to meet numerical VTWQS for several metals on numerous sampling occasions.

6.3 Step 2: Biological Measures of Impact

In addition to the evaluation of the chemical data in Step 1 of the Ecological Evaluation, several lines of biological evidence were examined to determine if significant impacts predicted by the VTWQS violations and HI's were being observed, including:

- *Surface water and sediment toxicity tests:* These tests involved the laboratory testing of surface water and sediments collected from the site using representative organisms. The survival, reproductive success, and growth of these organisms was measured over a period of time to assess the impact, if any, from the site's surface water or sediments.
- *Benthic Community Surveys:* These surveys measured the type and abundance of the bottom dwelling organisms that often serve as the food for fish communities. The quality of the benthic community is an indicator of the health (both density and diversity) of the aquatic community.
- *Fish abundance and species surveys:* These surveys (carried out by the USACE and the VT ANR) compared density and diversity levels among fish populations to levels expected for the type of river environment represented by the WBOR, and
- *Algae chemical analysis studies:* The purpose of these studies is to understand the potential for bioaccumulation in the food chain.

In viewing the risk potential for COCs in the Elizabeth Mine area, these lines of evidence must be "weighted" with respect to the emphasis placed on each. Actual direct measures of biological impairment are given greater emphasis than indirect measures of risk that evolve from the calculation of hazard indices.

6.3.1 Surface Water and Sediment Toxicity Tests

Toxicity tests were conducted to evaluate the effect of exposure to surface water and sediment from the Site on aquatic invertebrates and fish (Fathead Minnow, Amphipod – Scud, Bloodworm, and Water Flea). Toxicity tests evaluate cumulative effects of chemicals by introducing healthy organisms to Site surface water and sediment for a specific time period. For comparison, the same types of organisms were exposed to upstream (Reference) area surface water and sediment over the same test period. Two rounds of toxicity testing were performed, corresponding to the June and September 2000 EPA sampling events.

The results of the toxicity testing indicate that Source Area surface water and sediment is toxic to tested organisms. Nearly 100% of the organisms died as a result of exposure to the surface water and sediments from the Source Area. The Copperas Brook surface water was so toxic that even when it was substantially diluted (to levels as low as 10% of the original sample) with clean water, the test organisms died. All test organisms also died from exposure to surface water from sample Locations 8 (Air Vent before WBOR) and 12 (within WBOR just downstream of confluence with Copperas Brook). Location 13 (within the WBOR, near the Copperas Brook confluence) showed similar toxic

results in the sediment toxicity tests. All other areas tested did not show significant impacts.

Toxicity tests of water and sediment between the Air Vent and Copperas Brook (sample locations 9 and 10) indicate that contamination from the Air Vent does not significantly affect the survival, reproduction, or growth of organisms living in this area. Even though the Air Vent water itself is toxic to test organisms, the impact of the air vent discharge on WBOR appears to be rapidly dampened by dilution effects. The surface water toxicity tests suggest that impact to aquatic organisms does not reach EPA location 16, about 4000 feet (1250 meters) below the confluence with Copperas Brook. Figures 6 and 7 graphically show the results for the surface water and toxicity tests.

6.3.1.1 Summary of Key Findings for Surface Water and Sediment Toxicity Tests

- When exposed to surface water of Copperas Brook, or the Mixing Zone of the WBOR nearly all test organisms died no test in the Mixing Zone organisms survived in 3 tests and only 10% survived the fourth test in the Mixing Zone.)
- When exposed to the sediment of Copperas Brook or the section of the Mixing Zone Area near the confluence at EPA location 13, significant mortality death was also seen in the test organisms.
- The sediments Upstream of Mixing Zone, Air Vent Mixing Zone, lower section of Mixing Zone, and Below Mixing Zone Areas did not show toxic effects to test organisms growth, survival, and reproduction of all organisms tested with water from the Air Vent Mixing Zone were comparable to the Reference Area results.

6.3.2 Benthic Organism Community Data

Species diversity and density of benthic organism populations are key measures of the health of the river environment. Benthic organisms play an important role in the aquatic and sedimentary community within the WBOR and its tributaries. Many of the native aquatic predators (mainly fish) rely on benthic organisms as a food source. Contamination of surface water and sediment adversely affects the numbers and diversity of species of benthic organisms present, thereby affecting species that rely on these organisms for food.

Species density and diversity are severely depressed in Copperas Brook, the Mixing Zone and Affected Tributaries. The samples of the benthic community in the Air Vent Mixing Zone are similar in most respects to the upstream (Reference) Area and Ompompanoosuc River (below EBOR and WBOR confluence) samples. These results indicate that the Air Vent contribution to the WBOR contamination is not significant in terms of biological impact, even though water chemistry results indicate the potential for impacts to the aquatic organisms in this stretch of the river.

When compared to the VTWQS, the WBOR does not meet VTWQS for all three of the VT criteria evaluated for approximately 4.4 miles downstream of the confluence with Copperas Brook, near EPA location 29. The WBOR, however, does achieve VTWQS for 2 or the 3 measures by EPA Location 19, just upstream of Rices Mills. Figures 8 and 9 show the results for the epifauna survey. Statistical projections (plot of abundance and

richness over distance from source) confirm that the VTWQS for all criteria should be met on the stretch of the WBOR near Union Village Dam. The approximate distance downstream of the confluence with Copperas Brook where all state criteria are met in the WBOR is about 10,000 meters. Figure 12 shows these results.

Figures 10 and 11 show the results of the infauna survey. While there are no VTANR criteria for infauna, a general comparison of abundance and diversity can be made between locations upstream and downstream of Copperas Brook. The infauna results also suggest severe impact in the Source Area and Mixing Zone, with levels returning to normal downstream of the Mixing Zone.

6.3.2.1 Summary of Key Findings of the Benthic surveys

- The density and diversity of benthic water-dwelling species (epifauna) within the Mixing Zone is significantly lower than in the upstream (Reference) Area.
- The density of sediment-dwelling organisms (infauna) is impaired within the Mixing Zone; however, infauna diversity within the lower reaches of the Mixing Zone is similar to upstream (Reference) Area.
- Source Area samples show extremely low organism density and little diversity.
- Sediment-dwelling organism (infauna) density in the Source and Mixing Zone locations shows little difference from the upstream (Reference) Area. This may be due to the limited habitat within the WBOR.

6.3.3 Fish Abundance Surveys

Fish density and diversity are key measures in the evaluation and analysis of impacts to the WBOR and affected tributaries from the Elizabeth Mine. Even though only larger fish (like trout) are consumed by humans, the health of the forage fish community is a better indicator for ecological risk assessment, especially for contaminants with low bioaccumulation potential, as in the case of Elizabeth Mine. Because they can forage over large areas, predatory fish collected near the mine site may not be a good measure of the impact of the mine. Many of the trout occurring downstream of the mine are likely to be migrants from tributary streams. Moreover, the presence of even one large fish (trout) can have a substantial impact on the relatively low overall biomass in WBOR and thus data for total biomass of fish may be misleading. In contrast, forage fish are usually residential, i.e. spend most of their life in a localized area, and are thus a better indicator of site conditions. A reduced forage fish population will obviously result in reduced fish at higher levels within the food chain.

Studies by the USACE (1990) and VTANR (1987 and 2000) provide evidence that the Elizabeth Mine has had a severe impact on the fish communities in the WBOR and affected tributaries. In 1990, the USACE studied biomass of forage species fish (blacknose dace, longnose dace, slimy sculpin, longnose sucker) in two upstream and two downstream locations of the Copperas Brook. These locations represent similar habitats and thus any difference in fish communities can be attributed to the detrimental effects of mines. The USACE study showed that the biomass of the forage species upstream of the mine (4.5 kg/ha) was more than three times higher than biomass at the downstream locations (1.3 kg/ha).

A VTANR study of showed the fish density (i.e. number of fish per unit area) in upstream locations in the WBOR to be almost eight times the density found at locations downstream of Copperas Brook (18.6 fish/100 m² upstream vs. 2.5 fish/100 m² downstream, VTANR 1987). VTANR calculated an Index of Biotic Integrity (IBI) value for the USACE and VTANR stations. IBI measures ecological health of the fish community as a whole. Figure 14 (top plot) presents IBI as well as fish density for the USACE and VTANR data. The IBI in the upstream areas of WBOR is 39 (as compared to the VT threshold values for Class B waters of 29 to 31), whereas the IBI for the WBOR below Copperas Brook is only 9.

A study conducted by the VTANR in the tributaries of WBOR (Langdon, 1987) noted more than a ten-fold reduction of fish density in Lord Brook downstream (1.1 fish/100 m²) from the South Open Cut Source Area, as opposed to stretch of Lord Brook upstream of the South Open Cut Source Area influence which had a fish density of (10.7 fish/100 m²). No fish were found in the Copperas Brook. Sargent Brook shows a fish density (9.9 fish/100 m²) that is similar to unaffected areas of the Lord Brook. The IBI was found to be excellent for Sargent Brook (45 out of possible 45). Because of the small number of native species (for Lord and Copperas Brooks), the IBI could not be calculated. The study concluded that the impact of toxic levels of metals is likely to be responsible for the low density of fish in these areas.

6.3.3.1 Summary of Key Findings for Fish Abundance Surveys

- Fish species, biomass (total weight of fish within a given area), abundance, density, and metal content have been evaluated by previous Vermont Agency of Natural Resources (VTANR) and US Army Corps of Engineers (USACE) studies.
- The USACE 1990 study of the WBOR found the biomass and density of the forage species that are indicative of ecological damages is severely affected. The biomass and density of forage fish downstream of the mine were about one third than similar characteristics of the upstream reference areas.
- The VTANR 1987, 1998 and 2000 studies found even more severe detrimental effects of contaminants originating from the mines on fish communities in the tributaries of the Ompompanoosuc River. Contaminants eliminated all fish in Copperas Brook. The fish density in the affected areas of the Lord Brook was almost 1/10th lower than fish density in unaffected areas of the Lord Brook and in Sargent Brook.
- The Index of Biotic Integrity (IBI, a measure of ecological health of the fish community) was found to be depressed significantly from a value of 39 in the upstream areas of the WBOR (as compared to the VT threshold values for Class B waters of 29 to 31) to a value of 9 (well below the WQS threshold), in the downstream areas affected by the mine. The degradation of fish community health is supported by both USACE 1990 and VTANR 2000 studies.

6.3.4 Algae Chemical Analyses

Some fish and benthic invertebrates derive all or a portion of their nutrition by scraping algae from rock surfaces. As part of the ecological assessment, Bob Genter of Johnson

State College collected and analyzed algae samples from rock surfaces the WBOR, Copperas Brook, Lord Brook and other tributaries to the WBOR. Samples were collected by scraping the algal material off submerged boulders in the stream/river bed. Since it is difficult to separate algal material from metals flocculent and fine detritus, the samples likely reflect a combination of chemical precipitate, sediment, and biological material. Numerous (replicate) samples were collected at each sample station to ensure statistical validity in the results.

The samples from upper Lord Brook (Locations 39B and 43) show significantly greater metals concentrations than the Reference Areas (Sargent Brook and Location 39A in Lord Brook). In particular, copper concentrations are 1 to 2 orders of magnitude (10 to 100's of times) greater, and aluminum concentrations are 3 to 5 times greater than Reference Area levels. Copper and zinc concentrations in the Source Area (Copperas Brook) are unusually low (3 to 10 times lower than Reference Areas). This may be because the surface water is so toxic that most algae species cannot survive.

Within the Mixing Zone, copper concentrations in algae are generally 1 to 2 orders of magnitude (10 to 100's of times) higher than the upstream (Reference) Area at Tyson's Bridge (near EPA, Location 7), similarly zinc concentrations average 1 to 1.5 orders of magnitude (10 to 500 times) higher than upstream (Reference) Area concentrations. Algal metal concentrations within the Air Vent Mixing Zone are not significantly higher than the Upstream of Mixing Zone (Reference) Area. Copper concentrations Below the Mixing Zone remain consistently higher than the upstream (Reference) location by a factor of 5 to 10 times; zinc concentrations are also in the 5 to 10 times-higher range. Below the confluence of the EBOR and the WBOR (Location 44), the metals concentrations in algae remain significantly above the Upstream of the Mixing Zone (Reference) location levels as far downstream as has been measured to date.

6.3.4.1 Summary of Key Findings for Algae studies

- Significantly higher concentrations of some metals (copper, iron, and zinc) occurs in algal material within and below the Mixing Zone.
- Aluminum concentrations are generally high in Reference and downstream locations, but were 3 to 6 times greater in the Source Area and the Mixing Zone than in the Reference Area.
- Copper concentrations are one to two orders of magnitude (10 to 100's of times) higher in the Source Area than the Reference Area.
- Slight attenuation of copper concentrations is observed Below the Mixing Zone and below the WBOR/EBOR confluence.

7.0 Human Health Risk Studies

The human health exposure assessment is ongoing. At this point in the process it is only possible to evaluate whether the site data strongly suggests the need for an immediate

action to prevent exposure to contaminants found at the site. A more detailed evaluation of the potential long-term threats at the site will be the subject of the Baseline Human Health Risk Assessment that will be prepared as part of the Remedial Investigation/Feasibility Study (RI/FS).

EPA has sampled 10 residential wells in the area of the Site. Several of the water supplies adjacent to the Site were sampled numerous times in 2000. One water supply well did not meet federal drinking water standards for several metals (copper, cadmium). The residents and land owner were promptly notified. The residents have since re-located and the well is no longer in use. All of the other water supply wells were found to meet federal and state primary drinking water standards. Table 9 presents the residential water supply data collected to date.

EPA collected residential soil, indoor dust, and air samples from three residences. The soil data revealed a few instances where levels of iron, lead, and thallium warranted further study, because these levels were greater than background. The concentrations of these contaminants were not at levels considered to represent an acute (short term) hazard. Elevated lead levels were found in some of the residential dust samples. The source of the lead is not yet known. All of the water, soil, and dust data has been transmitted to the residents and the Vermont Department of Public Health. A more detailed evaluation of the soil and dust data will be presented in the Baseline Human Health Risk Evaluation.

EPA submitted the drinking water, soil, and dust data to the Agency for Toxic Substances and Disease Registry (ATSDR). The health consultation from ATSDR confirmed EPA's assessment that the residential water and soil data do not indicate any current risks that would warrant immediate EPA action. The Baseline Human Health Risk Assessment that will be developed as part of the RI/FS will more fully evaluate the current and future potential threats to human health and the environment including an assessment of the effects of long-term exposure to windblown dust and the exposed tailings.

8.0 Conclusions

8.1 Human Health Risk

Drinking water, residential soil, and residential dust sampling results do not suggest a short-term human health exposure above acceptable levels. Human health risk will be more fully evaluated as part of the Baseline Human Health and Ecological Risk Assessment.

8.2 Biological Impacts

This summary presents multiple lines of chemical and biological evidence regarding impacts to the biological community. Figure 14 provides an overall summary of all lines of evidence, indicating the extent of chemical and biological impact to the WBOR watershed from Elizabeth Mine source areas. Assessments of chemical and biological lines of evidence indicate that Site contaminants adversely affect the fish and benthic communities.

The biological community (benthic organisms and fish) is severely impacted in Copperas Brook, the upper reach of Lord Brook below the South Open Cut, and in the Mixing Zone of the WBOR below Copperas Brook. The biological community appears to recover to conditions similar to upstream (Reference locations) at some point below Union Village Dam, although algae metals concentrations remain high below the dam. Surface water and sediment collected from Copperas Brook, the first section of the Mixing Zone and the Air Vent are highly toxic to aquatic organisms such that survival of aquatic receptors in this area is not likely. The toxicity tests indicate that these impacts are not present below the Mixing Zone.

Collectively, the various lines of evidence suggest that EPA Location 44, situated downstream from Union Village Dam, represents the best estimate for the location where the WBOR is restored to upstream quality and the biological component of the VTWQS, even though chemical evidence from surface water sampling indicates the potential for concentrations above numerical VTWQS further downstream. The distance from the Copperas Brook confluence to EPA Location 44 is approximately 5.7 miles.

Since all of the lines of evidence show that Copperas Brook and the Mixing Zone are the most severely impacted, it can be inferred that TP-1, TP-2, and TP-3, which are the contaminant sources located within the Copperas Brook drainage, are the cause of the impacts to the WBOR. These impacts firmly support the need for an early cleanup action (NTCRA) to address the principal sources of acid mine drainage.

The EE/CA will further evaluate the cleanup options designed to restore the WBOR to Vermont biological standards for fresh water rivers. Additional studies are planned to assess impacts to fish populations and terrestrial receptors, including birds and small mammals. These studies will be integrated into the Baseline ERA and the Human Health Risk Assessment, scheduled for completion in 2002.

9.0 Glossary

AMD: acid mine drainage

Aquatic Species: animals, plants, and insects that live in water

ATSDR: Agency for Toxic Substances and Disease Registry

AWQC: Ambient Water Quality Criterion – EPA promulgated surface water quality standards under the Clean Water Act

BERA: Baseline Ecological Risk Assessment (a part of the second “Remedial” phase)

Benthic organisms: small, riverine bottom-dwelling animals

COC: Chemical of Concern

EBOR: The East Branch of the Ompompanoosuc River

Epifauna: animals/insects that live in water

ERA: Ecological Risk Assessment

GPM: Gallons per minute

HI: Hazard Index – sum of hazard quotients for individual metals

HQ: Hazard Quotient – ratio of measured contaminant concentration to the applicable criteria

Infauna: animals/insects that live in river sediments

NTCRA - Non-Time Critical Removal Action: – EPA approach to “rapid” site cleanup, operating under separate guidance from the Remedial or Emergency Response programs

Periphyton: algae

PPM: part per million – a measure of concentration (generally of contaminants in this case)

PRGs: Preliminary Remediation Goals established by EPA for soil contamination in various EPA Regions

Receptor: the ecological organisms (mammals, insects, fish, plants, etc) or humans who are potentially exposed to contamination

Reference Area: The river (WBOR) upstream of the tailings that is used as a benchmark in assessing the impacts of the mine – assumed to be representative of clean conditions.

RI/FS: Remedial Investigation/Feasibility Study - a detailed study completed under the CERCLA process to determine the nature and extent of contamination and to characterize all aspects of a given site in support of risk assessments and remedial designs.

SVOC – Semivolatile organic compound (e.g. polynuclear aromatic hydrocarbons as one example of this range of organic chemicals)

Terrestrial Receptor: “upland” species of birds, plants, mammals that may be exposed to contamination

TP: Tailings Pile – processed waste material from mining and milling operations

USACE: US Army Corps of Engineers (New England Division in Concord, MA)

VTANR: Vermont Agency of Natural Resources (Waterbury, VT)

WBOR: The West Branch of the Ompompanoosuc River

WQS: Water Quality Standards